DISCOVERY

Effect of nitrogen fertilizer on the growth of hybrid sorghum sudan grass

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ABSTRACT

A pot experiment was conducted at Experimental area, Agronomy Department PMAS - University of Arid Agriculture Rawalpindi to see the effect of different levels of nitrogen fertilizer on the growth and physiological traits of Sorghum Sudan Grass during March, 2022. Completely randomized designed was applied along with three replications. Seeds of Sorghum Sudan grass were collected from NARC Islamabad. Nitrogen fertilizer was applied in pots on 30th March, 2022, according to the treatments. Nitrogen played a significant role in the growth and physiology of Sorghum Sudan Grass. Nitrogen @ 150kgha^{-1} is the best among other four treatments and attained the highest plant heights in three times (21.355, 65.153 and 100.620 cm) respectively. However, results of nitrogen @ 200kgha^{-1} are approximately statistically at par with NPK. Nitrogen @ 150kgha^{-1} gained the highest position in two times data (0.7050 and 1.4250) respectively. Nitrogen @ 200kgha^{-1} gained less value than nitrogen @ 150kgha^{-1} might be excessive dose. Nitrogen nutrition played a key role in the enhancement of leaf area values; however, nitrogen @ 150 kgha^{-1} nutrition had the top position (1.140 and 1.950) during two times respectively. Leaf area index data had statistically significant results but among the nutrition treatments nitrogen @ 150kgha^{-1} nutrition is the best option attaining the highest values (91.475 and 152.550) respectively in two times. Nitrogen fertilizer at different levels had statistically significant effect on crop growth rate of sorghum plants; however, nitrogen @ 150kgha^{-1} nutrition treatment attained the highest value (0.5333) which was statically at par @ 200 kgha^{-1} nutrition treatment. Nitrogen @ 150 kgha^{-1} nutrition treatment had the top position (4061.9) but other three doses of nitrogen values having minute difference with nitrogen @ 150kgha^{-1} and higher than control. Four doses of nitrogen fertilizer produced more net assimilation rates than control and nitrogen @ 150kgha^{-1} gained the highest value (45.653) which was statistically at par with nitrogen @ 200kgha^{-1} (43.521). Nitrogen fertilizer is an inorganic fertilizer provides the nutrition to the plant fastly and provides better performance at nitrogen @ 150kgha^{-1}. Nitrogen @ 200kgha^{1} showed better performance than control but less than nitrogen @ 150kgha^{-1} therefore this finding improves the economics of the study.

Keywords: Forage Production, Economics of nutrition, Dry biomass and Physiological traits

1. INTRODUCTION

Sorghum Sudan Grass has well-known for its high production and weed inhibition properties, as well as for water-insufficiency, heat and salinity acceptance (Jung et al., 2015). It is effectively intercropped with winter forage grasses and fodders; ryegrass, barley fodder and rye in different intercropping ratios (Ji et al., 2010). This is extensively grown as summer forage globally. This grass is a capable basis for green fodder and qualitative hay/silage (Ali et al., 2014). It can provide green fodder along with more than one cutting; but its qualitative value is lower than maize fodder (Kim et al., 2012). In South Korea sorghum grass is the prime summer forage mixed with maize green chop and especially utilized in silage production (Seo et al., 2000). It is Approximately 26,491 hectares and 397,372-ton production during 2014 is under this grass that is near to 59% of the total summer forage crops area in South Korea (MAFRA, 2015).

Enhancement in production and forage values is must with the supply of nitrogenous fertilizer (Turgut et al., 2005). This fodder has very much relation with this macro nutrient. Sorghum fodder attains maximum nutrients from soil to fulfill its nutrients requirement (Lopez-Bellido et al., 2006; Marsalis, 2006; Khosla et al., 2000). Beyaert and Roy, (2005) concluded that 125 kgN attained maximum production and showed the most economical dose (83 to 107 $kgha^{-1)}$. Two equal applications of N improved NUE and apparent N recovery (ANR) more than single dose (Beyaert and Roy, 2005). 222 kg N ha^{-1} in split doses enhanced forage along with more N uptake efficiency (Kilcer et al., 2002). N application in splits had economical effect on wheat produce under different nitrogen application times (Prokopy and Widhalm, 2011).

Rural families or small farmers have 30 million cattle, 27 million buffalos, 54 million goats, 27 million sheep and 1 million camels (Rehman et al., 2017; Tahir et al., 2019). Livestock requires green fodder in huge amounts in Pakistan. 11.5% share in total GDP is attained by livestock sector in Pakistani Economics (Govt of Pakistan, 2021). Reducing in plant population and Nitrogen fertilizer adversely affects fodder production and deteriorates nutritive quality of sorghum and corn under less irrigation conditions (Marsalis et al., 2009). Application of nitrogen attains maximum benefit for a crop at proper requirement time. Fertilizer knifed-in at planting produced maximum grain production than broadcast (Khosla et al., 2000; OMAF, 2002). Multicut sorghum forage requires N fertilizer before planting and after each cut (Ketterings et al., 2004; Rahman et al., 2001; Lauriault et al., 2002; Eltelib, 2004). Fresh and dry forage produce of multi cut sorghum enhanced rapidly with urea application (Khair and Salih, 2007; Eltelib, 2004; Neylon et al., 2002; Reddy et al., 2003).

Production enhancement in forage production should be kept in mind to optimize N application under economic efficiency and soil pollution mitigation (Hirel et al., 2001; Moon et al., 2010; Tamme et al., 2009; Brady and Weil, 2008; Liu et al., 2014). N_2O emission to the atmosphere (Pollution) is mostly caused by N fertilization resulting ozone diminution and global warming (Nadeem et al., 2012; Solomon, 2007). More N fertilizer produces taller plants, as N increases plant growth (Turgut et al., 2005; Rizan et al., 2003; Sher et al., 2016; Gebremariam and Assefa, 2015; Liu et al., 2014). Moghimi and Emam, (2015) investigated that N rates significantly enhanced leaf width and ultimately leaf area index and stem diameter also increased with more N (Clough et al., 2003; Ayub et al., 2002; Afzal et al., 2013; Almodares et al., 2006; Kilcer et al., 2002; Beyaert and Roy, 2005; Ketterings et al., 2007; Lopez-Bellido et al., 2006; Howard et al., 2001; Clay et al., 2001; Howard et al., 200; Nicholos et al., 2004).

Amount of biomass accumulated by the plant per unit of leaf area at a given time (g $cm^{-2}day^{-1}$) is called Net assimilation rate (NAR (Carpio et al., 2016; Escalante and Kohashi, 2014; Mora et al., 2006). Nitrogen increases growth and higher biomass yields (Maheswari et al., 2017). Application of nitrogen fertilizers more than its demands causes intoxication (Villareal et al., 2002). Soil analysis is must to apply any kind of nutrient before plantation to save the nutrients and avoids the soil from pollution (Sosa and Garcia, 2018; Pichardo et al., 2007; Pacheco and Cabresa, 2003). Therefore, this pot experiment was carried out to investigate the effect of nitrogenous fertilizer on the growth and physiological traits of Sorghum Sudan Grass.

2. MATERIALS AND METHODS

A pot experiment was conducted at Experimental area, Agronomy Department PMAS- University of Arid Agriculture Rawalpindi to see the effect of nitrogen fertilizer on the growth and physiological traits of Sorghum Sudan Grass during March, 2022. Completely randomized designed was applied along with three replications. Treatments were; T_1 = Control (without Nitrogen), T_2 = 50 kg Nha^{-1} (49.5mg X10 = 495.6 mg $NPot^{-1}$), T3 = 100 kg Nha^{-1} (99mg X 10 = 990 mg $NPot^{-1}$), T_4 = 150kg Nha^{-1} (148.5mg X 10 = 1485 mg $NPot^{-1}$) and T_5 = 200kg Nha^{-1} (198mg X 10 = 1980 mg $NPot^{-1}$). Seeds of Sorghum Sudan grass were collected from NARC Islamabad. 10 seeds of Sorghum Sudan grass were sown in each pot having 10 kg soil. Three plants were maintained in each pot.

Nitrogen fertilizer was applied in pots on (30^{th} March, 2022) according to the treatments. All other agronomic practices were applied similarly. Growth parameters i.e., Plant Height (cm), Leaf Diameter (cm), Leaf Area (m^2), Net Assimilation Rate (NAR)

[g/m²/day or week), Crop Growth Rate (CGR) (g/m²/day or week), Leaf Area Duration (LAD) (cm² day or week) and Leaf Area Index (LAI) were determined during crop duration.

3. RESULTS AND DISCUSSIONS

Nitrogen played a significant role in the growth and physiology of Sorghum Sudan Grass. The results of plant height, leaf diameter and leaf area as affected by different doses of nitrogen are presented in table-1. Plant height is a main contributor in plant growth of soybean crop. Table-1 showed statistically significant results of plant height in different three intervals. Nitrogen @ 150kgha^{-1} is the best among other four treatments and attained the highest plant heights in three times (21.355, 65.153 and 100.620 cm) respectively. However, results of nitrogen @ 200kgha^{-1} are approximately statistically at par with NPK. This minute difference in plant height is might due to excessive nitrogen supplementation. The increasing trend in plant height was observed in all the treatments with the passage of time but the maximum at nitrogen @ 150kgha^{-1} treatment. The findings of the study are in line with the investigations of (Maughen et al., 2012; Haankuku et al., 2014; Turgut et al., 2007; Damien et al., 2017; Restellatto et al., 2013; Marsalisa et al., 2009; Coblentz et al., 2017; Nakano et al., 2011; Khalid et al., 2003; Sarker, 2000).

Table 1 Effect of Nitrogen fertilizer on the growth and physiological trait of Hybrid Sorghum Sudan Grass

Treatments	Plant Height (cm)			Leaf diameter (cm)		Leaf Area (m²)	
	30th March	13rd April	27th April	6th April	27th April	6th April	27th April
T_1 (0 kg Nha^{-1})	18.845b	47.480b	70.867c	0.2250c	0.5667b	0.3167c	0.5633c
T_2 (50 kg Nha^{-1})	19.783ab	52.578ab	84.995b	0.2433c	0.7000b	0.4725bc	0.8700b
T_3 (100 kg Nha^{-1})	20.333a	62.227a	91.668a	0.4400b	1.2250a	0.9375ab	1.1500b
T_4 (150 kg Nha^{-1})	21.355a	65.153a	100.620a	0.7050a	1.4250a	1.1400a	1.9050a
T_5 (200 kg Nha^{-1})	20.012a	60.231a	88.256ab	0.5512ab	1.3150a	1.0020a	1.4902ab
LSD	2.201	17.670	12.364	0.2412	0.8573	0.2493	0.7205

Means followed by different letter (s) within the columns differ significantly at 5% level of significance

Growth of every plant is determined by the leaf diameter of the plant. Statistically significant results during two times were indicated in table-1. Nitrogen @ 150kgha^{-1} gained the highest position in two times data (0.7050 and 1.4250) respectively. Nitrogen @ 200kgha^{-1} gained less value than nitrogen @ 150kgha^{-1} might be excessive dose. This finding saved the nitrogen fertilizer and improves the economics. All the doses of nitrogen performed better performance than without nitrogen. The study results of this parameter are in agreement of the results (Roy and Khandakar, 2010; Zewdu et al., 2002b; Khaleduzzaman et al., 2007; Tassema et al., 2003; Kumar et al., 2001; Saha et al., 2001; Uddin et al., 2005a; Singh et al., 2000; Lee and Lee, 2000).

Leaf area is a vegetative growth parameter directly related to the photosynthesis and depicted statistically significant results in table-1. Nitrogen nutrition played a key role in the enhancement of leaf area values; however, nitrogen @ 150kgha^{-1}nutrition had the top position (1.140 and 1.950) during two times respectively. Without nitrogen nutrition minimum leaf area was observed in control treatment (0.3167and 0.5633) respectively in two times. Similar results were also found in the investigations of (Rahman et al., 2001; Maughen et al., 2012; Haankuku et al., 2014; Turgut et al., 2007; Marsalisa et al., 2009; Damien et al., 2017; Restellatto et al., 2013; Belanger et al., 2017). Growth and physiology of plant are the important contributors of the plant life. Physiological traits; leaf Area index (LAI), Crop Growth rate (CGR), Leaf Area Duration (LAD) and Net Assimilation Rate (NAR) results were depicted in table-2. Nutrition played a key role in the growth as well as physiology of soybean crop.

Leaf area index data had statistically significant results (Table-2) but among the nutrition treatments nitrogen @ 150kgha^{-1} nutrition is the best option attaining the highest values (91.475 and 152.550) respectively in two times. Four nitrogen nutrition treatments performed better than control i.e., without nutrition. Leaf area index refers to the efficiency of photosynthetic process. It is the ratio of total leaves area to the ground cover, which increases to maximum after crop emergence (Reddy, 2004). These results are closely related to the conclusions of (Aguilar et al., 2005; Koutroubas et al., 2008; Zubillaga et al., 2002; Snyder and Tegeder, 2021; Hassan et al., 2020; Ashraf et al., 2019; Evans and Clarke, 2019; Khaliq et al., 2008; Nasim et al., 2012; Al Hasnawi et al., 2020; Beig et al., 2010; Zhang et al., 2014; Naz and Sulaiman, 2015; Smith & Siciliano, 2015; Trinh et al., 2015; Anggoro, 2011; Thind et al., 2009; Min et al., 2019).

Table 2 Effect of Nitrogen fertilizer on physiological traits of Hybrid Sorghum Sudan Grass

Treatments	LAI		CGR (g/m²/day)	LAD (cm²/day)	NAR (g/m²/day)
	6th April	27th April			
T_1 (0 kg Nha^{-1})	26.767c	45.000c	0.1783b	1354.3c	38.544b
T_2 (50 kg Nha^{-1})	37.900bc	69.750bc	0.1987b	1541.8bc	40.371ab
T_3 (100 kg Nha^{-1})	54.950b	91.750b	0.3448ab	2563.6b	42.091ab
T_4 (150 kg Nha^{-1})	91.475a	152.550a	0.5333a	4061.9a	45.653a
T_5 (200 kg Nha^{-1})	72.762ab	122.150ab	0.4356a	3250.2a	43.521a
LSD	32.054	53.079	0.3321	2701.2	7.009

LAI= Leaf Area Index, CGR= Crop growth Rate, LAD= Leaf Area Duration, NAR= Net Assimilation Rate
Means followed by different letter (s) within the columns differ significantly at 5% level of significance

Crop growth rate is a fundamental determinant of plant physiology. Proper nutrition availability is the basic requisite of the plant for the better performance in growth as well as plant physiology. Nitrogen fertilizer at different levels had statistically significant effect on crop growth rate of sorghum plants, however nitrogen @ 150$kgha^{-1}$ nutrition treatment attained the highest value (0.5333) which was statically at par @ 200$kgha^{-1}$ nutrition treatment (Table-2). Organic fertilizers are the good sources of macro and micro nutrients and environmentally approach. Crop growth rate is the dry matter production per unit time which is affected by temperature, solar radiation, age of cultivar and water/nutrient supply. Micronutrients application enhances the plant growth through increased photosynthesis and other plant pathways (Reddy, 2004). Dry weight increase in time interval in relation to the initial weight expresses the relative growth rate (RGR) while crop growth rate is an absolute measure of growth, therefore, similar values could be expected for different initial weights (Reddy, 2004). Similar findings were obtained by the results of (Nasim et al., 2011; Wang et al., 2013; Javeed et al., 2021; Perveen et al., 2021; Ghafoor et al., 2021; Glass, 2003; Ahmad et al., 2018; Jin et al., 2010; Zahoor et al., 2010; Wajid et al., 2010; Zubillaga et al., 2002; Abbadi and Gerendas, 2009; De La Vega and Hall, 2002; Tovar et al., 2021).

Leaf area duration (LAD) results were statistically significant with the application of NPK, FYM and poultry manure nutrition (Table-2). This physiological trait is mainly dealt with plant leaf physiology and nutrition showed significant values as presented in table-2. Nitrogen @ 150$kgha^{-1}$ nutrition treatment had the top position (4061.9) but other three doses of nitrogen values having minute difference with nitrogen @ 150$kgha^{-1}$ and higher than control. Leaf area duration provides means for comparing various treatments on the basis of leaf persistence which reflects the extent of light interception and it is directly associated with leaf area index (Reddy, 2004). These results are supported by those of (Nasim et al., 2017; Ahmad et al., 2018; Hassan et al., 2021; Li *et* al., 2018; Wajid et al., 2012).

Net assimilation rate (NAR) is an important physiological trait in the growth and plant physiology and showing positive results with application of nutrition as indicated in table-2. Four doses of nitrogen fertilizer produced more net assimilation rates than control and nitrogen @ 150$kgha^{-1}$ gained the highest value (45.653) which was statistically at par with nitrogen @ 200$kgha^{-1}$ (43.521). Nitrogen fertilizer is an inorganic fertilizer provides the nutrition the plant fastly and provides better performance at nitrogen @ 150$kgha^{-1}$. Nitrogen @ 200$kgha^{-1}$ showed better performance than control but less than nitrogen @ 150$kgha^{-1,}$ therefore this finding improves the economics of the study. Net assimilation rate (NAR) refers the plant capacity to increase dry weight in terms of area of its assimilatory surface. It represents the photosynthetic efficiency in the overall sense and in connection with relative growth rate (Reddy, 2004). Different factors influence the NAR such as temperature, light, CO_2, water, leaf age, mineral elements, chlorophyll and genotype (Reddy, 2004). Supporting findings of this study are found by the scientists of (Cantarella et al., 2018; Manzoor et al., 2021; Mandal et al., 2016; Rasuli et al., 2021; Garcia et al., 2018; Perveen et al., 2021; Jin et al., 2010; Koutroubas et al., 2008; Nasim et al., 2017; Geng et al., 2016).

4. CONCLUSION

Availability of macro nutrients (NPK) to the plant fastly through the combined NPK fertilizer treatment attained the highest values of growth and physiological traits of soybean plants.

Ethical approval

Not applicable.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Abbadi J, Gerendas J. Nitrogen use efficiency of safflower as compared to sunflower. J Plant Nutr 2009; 32:929–945.
2. Afzal M, Ahmad A, Zamir S. Performance of multi cut forage sorghum under various sowing methods and nitrogen application rates. J Anim Plant Sci 2013.
3. Aguilar GL, Escalante EJA, Fucikovsky ZL, Tijerina ChL, Engleman CEM. Leaf area, net assimilation rate, yield and population density in sunflower. Terra Latinoamericana 2005; 23(3):303–310.
4. Ahmad MI, Ali A, He L, Latif A, Abbas A, Ahmad J, Zulfqar Ahmad M, Asghar W, Bilal M, Mahmood MT. Nitrogen effects on sunflower growth: A review. Int J Biosci 2018; 12:91 –101.
5. Al Hasnawi RA, AlJanaby ZAA, Jaafer AA, Mohammed RJ. Effect of nitrogen fertilization and irrigation water quality on some soil characteristics, growth and yield of sunflower. Plant Arch 2020; 20(1):2703–2705.
6. Ali HG, Alkhamisi VA, Nadaf SK, Al-Bakri AN. Forage productivity of three introduced sorghum × sudan grass hybrids under irrigation in three arid areas in Oman. Jordan J Biol Sci 2014; 10:716-724.
7. Almodares A, Darany SM. Effects of planting date and time of nitrogen application on yield and sugar content of sweet sorghum. J Environ Biol 2006; 27:601-605.
8. Anggoro DD. Producing slow-release urea by coating with starch/acrylic acid in fluid bed spraying. Int J Eng Technol 2011; 707–712.
9. Ashraf A, Ristina SS, Asad M, Hasan M, Qamar H, Mudassar M, Raza MU, Anum W, Abbasi W, Arshad A. Variability and correlation study of different newly developed sunflower hybrids in Pakistan. Int J Biosci 2019; 14(2):398–408.
10. Ayub M, Nadeem MA, Tanveer A, Husnain A. Effect of different levels of nitrogen and harvesting times on the growth, yield and quality of sorghum fodder. Asian J Plant Sci 2002; 4:304-307.
11. Beig B, Niazi MBK, Jahan Z, Hussain A, Zia MH, Mehran MT. Coating materials for slow release of nitrogen from urea fertilizer: A review. J Plant Nutr 2010; 43:1510–1533.
12. Belanger G, Thivierge M, Chantigny M, Seguin P, Vanass A. Nutritive value of sweet pearl millet and sweet sorghum as influenced by N fertilization. Can J Plant Sci 2017; 98(2).
13. Beyaert RP, Roy RC. Influence of nitrogen fertilization on multi-cut forage sorghum sudangrass yield and nitrogen use. Agronomy J 2005; 97:1493-1501.
14. Brady N, Weil R. Soil colloids: Seat of soil chemical and physical acidity. Pearson Education Inc: Upper Saddle River, NJ, USA 2008; 311-358.
15. Cantarella H, Otto R, Soares JR, De Brito Silva AG. Agronomic efficiency of NBPT as a urease inhibitor: A review. J Adv Res 2018; 13:19–27.
16. Carpio CA, Escalante EJAS, Aguilar MI. Analysis of growth and yield of maize in warm climate according to genotype, biofertilizer and nitrogen. Terra Latinoam 2016; 33(1):51–62.
17. Clay DE, Clay SA, Liu Z, Reese C. Spatial variability of C-13 isotopic discrimination in corn (*Zea mays*). Comm Soil Sci Plant Anal 2001; 32.
18. Clough A, Malcolm NH. Stem diameter: A rapid accurate parameter for monitoring growth of sorghum. Proceedings of the 11th Australian Agronomy Conference 2003.
19. Coblentz W, Akins M, Cavadini J, Jokela W. Net effects of nitrogen fertilization on the nutritive value and digestibility of oat forages. J of Dairy Sci 2017; 100:1739-1750.
20. Commonwealth of Virginia. Virginia Nutrient Management Standards and Criteria. Department of Conservation and Recreation, Division of Soil and Water Conservation, Commonwealth of Virginia 2014.
21. Damian J, Da Ros C, Da Silva R, Coldebella I, Simon DN, P or K doses on the dry matter and crude protein yield in

maize and sorghum for silage. Pesqui Agropecu Trop 2017; 47(1).
22. De la Vega AJ, Hall AJ. Effects of planting date, genotype and their interactions on sunflower yield: I. Determinants of Oil-Corrected Grain Yield. Crop Sci 2002; 42:1191–1201.
23. Eltelib HAM. Effect of nitrogen application on growth yield and quality of four forage sorghum cultivars. Msc. Thesis, Univ. of Khartoum, Sudan 2004.
24. Escalante EJAS, Kohashi SJ. Bean Yield and Growth. Manual for Data Collection, Colegio de Postgraduados, Montecillo, TX, USA 2014.
25. Evans JR, Clarke VC. The nitrogen cost of photosynthesis. J Exp Bot 2019; 70(1):7–15.
26. Garcia PL, Gonzalez-Villalba HA, Sermarini RA, Trivelin PCO. Nitrogen use efficiency and nutrient partitioning in maize as affected by blends of controlled-release and conventional urea. Arch Agron Soil Sci 2018; 64:1944–1962.
27. Gebremariam G, Assefa D. Nitrogen fertilization effect on grain sorghum (*Sorghum bicolor* L. Moench) yield. Int J of Agricultural Res 2015; 10:14-23.
28. Geng J, Chen J, Sun Y, Zheng W, Tian X, Yang Y, Zhang M. Controlled release urea improved nitrogen use efficiency and yield of wheat and corn. Agron J 2016; 108:1666–1673.
29. Ghafoor I, Habib-ur-Rahman M, Ali M, Afzal M, Ahmed W, Gaiser T, Ghafar A. Slow-release nitrogen fertilizers enhance growth, yield, NUE in wheat crop and reduce nitrogen losses under an arid environment 2021; 28:1–16.
30. Govt of Pakistan. Economic survey of Pakistan 2009-10. Finance Division, Economic Advisors wing. Islamabad, Pakistan 2021; 23.
31. Haankuku C, Epplin FM, Kakani VG. Forage sorghum response to nitrogen fertilization and estimation of production cost. Agron J 2014; 106(5):1659-1666.
32. Hassan MU, Islam MM, Wang R, Guo J, Luo H, Chen F, Li X. Glutamine application promotes nitrogen and biomass accumulation in the shoot of seedlings of the maize hybrid ZD958. Planta 2020; 251(3):1–15.
33. Hassan MU, Rasool T, Iqbal C, Arshad A, Abrar M, Abrar MM, Rahman MHU, Noor MA, Sher A, Fahad S. Linking plants functioning to adaptive responses under heat stress conditions: A mechanistic review. J Plant Growth Regul 2021; 9:1–18.
34. Hirel B, Bertin P, Quilleré I, Bourdoncle W, Attagnant C, Dellay C, Gouy A, Cadiou S, Retailliau C, Falque M. Towards a better understanding of the genetic and physiological basis for nitrogen use efficiency in maize. Plant Physiol 2001; 125:1 258-1270.
35. Howard DD, Gwathmey CO, Essington ME, Roberts RK, Mullen MD. Nitrogen fertilization of no-till cotton on loess-derived soils. Agron J 2001; 93:157-163.
36. Javeed HMR, Ali M, Qamar R, Shehzad M, Rehman H, Nawaz F, Jamil M, Ahmad A, Farooq A, Masood N, Zamir SI. Effect of date biochar pyrolyzed at different temperature on physiochemical properties of sandy soil and wheat crop response. Commun Soil Sci Plant Anal 2021; 52:1–15.
37. Ji HC, Lee SH, Yoon SH, Kwon OD, Choi GJ, Kim WH, Kim KY, Lim YC. Growth, forage production and quality of sorghum, sorghum × sudangrass and sudangrass hybrids at paddy field in southern region of Korea. J Kor Grassl Forage Sci 2010; 30(2):109-114.
38. Jin J, Liu X, Wang G, Mi L, Shen Z, Chen X, Herbert SJ. Agronomic and physiological contributions to the yield improvement of soybean cultivars released from 1950 to 2006 in Northeast China. Field Crop Res 2010; 115:116–123.
39. Jung JS, Lee K, Choi KC, Ji HJ, Park HS, Kim WH, Young YJ, Lee SH, Lee SH. Effect of seeding method and pre-emergence herbicides on plant growth and the production of sorghum × sudangrass hybrid. J Kor Grassl Forage Sci 2015; 35:17-25.
40. Ketterings QM, Cherney JH, Godwin G, Kilcer TE, Barney P, Beer S. Nitrogen management of brown midrib sorghum × sudan grass in the north eastern USA. Agron J 2007; 99:1345-1351.
41. Ketterings QM, Godwin G, Cherney JH, Beer S, Kilcer TF. Nitrogen management for brown midrib sorghum sudangrass: Results of two years of studies at the Mt. Pleasant Research Farm. What's Cropping Up 2004; 14(2):5-6.
42. Khair MAM, Salih SA. Dry matter yield and quality of some winter sown forage crops in Gezira, Sudan. J of Agric Sci 2007; 15 (2):204-219.
43. Khaleduzzaman ABM, Islam N, Khandaker ZH, Akbar MA. Effect of different doses of Nitrogen and phosphorus fertilizer on yield and quality of Napier grass (*pennisetum purpureum*). Bangladesh J Anim Sci 2007; 36(1-2):41-49.
44. Khalid M, Ijaz A, Muhammad A. Effect of nitrogen and phosphorus on the fodder yield and quality of two sorghum cultivars (*Sorghum bicolor* L.). Int J Agri Biol 2003; 5(1):61-63.
45. Khaliq T, Ahmad A, Hussain A, Ranjha AM, Ali MA. Impact of nitrogen rates on growth, yield and radiation use efficiency of maize under varying environments. Pak J Agric Sci 2008; 4 5:1–7.

46. Khosla R, Alley MM, Davis PH. Nitrogen management in no-till age grain sorghum production: I. Rate and time of application. Agron J 2000; 92:321-328.
47. Kilcer T, Ketterings Q, Katsvairo T, Cherney J. Nitrogen management for sorghum sudangrass: How to optimize N uptake efficiency? What's Cropping Up 2002; 12:6-9.
48. Kim JD, Ko KH, Kwon CH. Effect of heading and BMR types on the agronomic characteristics, forage yield and quality of sorghum × sudangrass hybrid. J Kor Grassl Forage Sci 2012; 32 :293-300.
49. Koutroubas SD, Papakosta DK, Doitsinis A. Nitrogen utilization efficiency of safflower hybrids and open-pollinated varieties under Mediterranean conditions. Field Crop Res 2008; 107:56–61.
50. Kumar A, Jaiswal RS, Verma ML, Joshi YP. Effect of nitrogen level and cutting management on yield and quality of different varieties of oat fodder. Indian J Anim Nutr 2001; 18 (3):262-266.
51. Lauriault LM, Kirksey RE, Donart GB. Irrigation and nitrogen effects on tall wheat grass yield in the southern high plains. Agron J 2002; 94:792-797.
52. Lee HS, Lee ID. Effect of nitrogen fertilizer levels on the dry matter yield, quality and botanical composition in eight-species mixtures. Korean J Anim Sci 2000; 42:727-734.
53. Li R, Wang JJ, Zhang Z, Awasthi MK, Du D, Dang P, Wang L. Recovery of phosphate and dissolved organic matter from aqueous solution using a novel CaO-MgO hybrid carbon composite and its feasibility in phosphorus recycling. Sci Total Environ 2018; 642:526–536.
54. Liu CW, Sung Y, Chen BC, Lai HY. Effects of nitrogen fertilizers on the growth and nitrate content of lettuce (*Lactuca sativa* L.). Int J Environ Res Public Health 2014; 11(4):4427-4440.
55. Lopez-Bellido L, Lopez-Bellido RJ, Lopez-Bellido FJ. Fertilizer nitrogen efficiency in durum wheat under rain fed Mediterranean conditions: Effect of split application. Agron J 2006; 98:55-62.
56. Maheswari MA, Murthy NG, Shanker AK. Nitrogen nutrition in crops and its importance in crop quality, Nitrogen nutrition in crops and its importance in crop quality, in Be Indian Nitrogen Assessment. Sources of Reactive Nitrogen, Environmental and Climate Effects, Management Options and Policies. Section B: Nitrogen Processes in the Biosphere, YP Abrol, TK Adhya, Singh, Eds., Elsevier, Amsterdam, Netherlands 2017.
57. Mandal S, Thangarajan R, Bolan NS, Sarkar B, Khan N, Ok YS, Naidu R. Biochar-induced concomitant decrease in ammonia volatilization and increase in nitrogen use efficiency by wheat. Chemosphere 2016; 142:120–127.
58. Manzoor S, Rahman MHU, Haider G, Ghafoor I, Ahmad S, Afzal M, Nawaz F, Iqbal R, Yasin M, Haq T, Danish S, Ghafar A. Biochar and slow-release nitrogen fertilizer improve growth, yield, NUE, fiber quality of cotton and reduce nitrogen losses under arid climatic conditions. Environ Sci Pollut Res 2021; 11:1–14.
59. Marsalis MA. Sorghum forage production in New Mexico (Guide A-332). New Mexico State University Cooperative Extension Service 2006.
60. Marsalis MA, Angadi F, Contras Govea E. Effect of seeding and nitrogen rates on limited irrigation corn and forage sorghum yield and nutritive value. In Abstracts: Annual meeting, Cestern Society of crop Science, Fort Collins, Co 2009.
61. Marsalisa M, Angadia S, Contreras-Goveab F. Dry matter yield and nutritive value of corn, forage sorghum and BMR forage sorghum at different plant populations and nitrogen rates. Field Crops Res 2009; 16(2):52-57.
62. Maughan M, Voigt T, Parrish A, Bollero G, Rooney W, Lee DK. Forage and energy sorghum responses to nitrogen fertilization in central and southern illinois. Agron J 2012; 104 (4):1032-1040.
63. Min KJ, Kim D, Lee JD, Lee KJ, Park KY. Characteristics of vegetable crop cultivation and nutrient releasing with struvite as a slow-release fertilizer. Environ Sci Pollut Res 2019; 26(33) :34332–34344.
64. Ministry of Agriculture, Food and Rural Affairs (MAFRA). Main Statistics in Agriculture, Livestock and Food 2015.
65. Moghimi N, Emam Y. Growth and yield responses of two forage sorghum cultivars to different nitrogen fertilizer rates. Iran Agric Res 2015; 34:39-45.
66. Moon YH, Kwon YR, Ahn BK, Lee JH, Choi DC. Determination of nitrogen fertilizer recommendation rates estimated by soil-testing for different types of paddy soils. Korean J Environ Agric 2010; 29:33-38.
67. Mora AR, Ort´ız-Cereceres J, Rivera-Peña A, Mendoza-Castillo MC, Colinas-Le´on MT, Lozoya-Saldaña H. Efficiency indexes of potato genotypes established under rained conditions. Rev Chapingo Ser Hortic 2006; 12(1):85–94.
68. Nadeem S, Hansen S, Azzaroli Bleken M, Dörsch P. N_2O emission from organic barley cultivation as affected by green manure management. Biogeosciences 2012; 9:2747-2759.
69. Nakano H, Hattori I, Sato K, Morita S. Early Planting and Early Nitrogen Application Increase Stem Total

Digestible Nutrient Concentration and Yield of Forage Rice in Southwestern Japan. Plant Prod Sci 2011; 14(2).
70. Nasim W, Ahmad A, Ahmad S, Nadeem M, Masood N, Shahid M, Fahad S. Response of sunflower hybrids to nitrogen application grown under different agro-environments. J Plant Nutr 2017; 40:82–92.
71. Nasim W, Ahmad A, Hammad HM, Chaudhary HJ, Munis MFH. Effect of nitrogen on growth and yield of sunflower under semi-arid conditions of Pakistan. Pak J Bot 2012; 44:639 –648.
72. Nasim W, Ahmad A, Wajid A, Akhtar J, Muhammad D. Nitrogen effects on growth and development of sunflower hybrids under agro-climatic conditions of Multan. Pak J Bot 2011; 43:2083–2092.
73. Naz MY, Sulaiman SA. Slow-release coating remedy for nitrogen loss from conventional urea: A review. J Control Release 2015; 225:109–120.
74. Neylon JM, Ebling TL, Taylor CC, Lynch MP, Reddish MA, Endres MI, Kung Jr L. The effects of height of cutting, hybrid and stage of maturity at harvest on the nutritive value of corn silage for lactating dairy cows. J Dairy Sci 2002; 85(1):383.
75. Nicholos SP, Snipes CE, Jones. Cotton growth, lint yield and fibre quality as affected by row spacing and cultivar. J Cotton Sci 2004; 8:1-12.
76. Ontario Ministry of Agric and Food (OMAF). Agronomy guide for field crops. Publ. 610, OMAF, Queens Printer for Ontario, Toronto 2002.
77. Pacheco AJ, Cabresa SA. Main sources of nitrogen in groundwater. Ingenier´ıa Revista Acad´emica 2003; 7(2):47–54.
78. Perveen S, Ahmad S, Skalicky M, Hussain I, Rahman MHU, Ghafar A, Bashir MMS, Batool M, Brestic M, Fahad S, Hassan M, Sabagh AE. Assessing the potential of polymer coated urea and sulphur fertilization on growth, physiology, yield, oil contents and nitrogen use efficiency of sunflower crop under arid environment. J Agron 2021; 11(269):1–12.
79. Pichardo RJC, Escalante JA, Rodrıguez MT, S´anchez GPG. Divided application and agronomic efficiency of nitrogen, water and radiation use and bean yield. Terra Latinoam 2007; 25(2):145–154.
80. Prokopy L, Widhalm M. Corn split NDST: Determine the feasibility and profitability of using post-planting nitrogen application for corn production 2011.
81. Rahman M, Fukai S, Blamey FPC. Forage production and nitrogen uptake of forage sorghum, grain sorghum and maize as affected by cutting under different nitrogen levels. In: Proceedings of the 10th Australian agronomy conference, Hobart, Australia 2001.
82. Rasuli F, Owliaie H, Najaf GM, Adhami E. Effect of biochar on potassium fractions and plant-available P, Fe, Zn, Mn and Cu concentrations of calcareous soils. Arid Land Res Manag 2021; 36:1–26.
83. Reddy SS, Shivaraj B, Reddy VC, Ananda MG. Direct effect of of fertilizer and residual effect of organic manures on yield and nutrient uptake of maize (*Zea mays* L.) in groundnut-maize cropping system. Crop Res Hsiao 2005; 29(3):390-395.
84. Rehman A, Jingdong L, Chandio AA, Hussain I. Livestock production and population census in Pakistan: Determining their relationship with agricultural GDP using econometric analysis. Information Processing in Agriculture 2017; 4:168–17 7.
85. Restelatto R, Pavinato P, Sartor L, Paixao S. Production and nutritional value of sorghum and black oat forage under nitrogen fertilization. Grass Forage Sci 2013; 69(4).
86. Rizwan M, Maqsood M, Rafiq M, Saeed M, Ali Z. Maize (*Zea mays* L.) response to split application of nitrogen. Int J of Agricultural Biology 2003; 5:19-21.
87. Roy PRS, khandakar ZH. Effect of Phosphorus fertilizer on yield and nutritional value of sorghum (*sorghum bicolor*) fodder at three cuttings. Bangladesh J Anim sci 2010; 39(1-2):106-115.
88. Saha NK, Shahjalal M, Khan MJ, Al-Mamun M. Evaluation of maize and oat forages on the basis of biomass yield and nutritive value. Prog Agri 2001; 12:175-181.
89. Sarkar B. Effect of different doses of nitrogen fertilizer on growth, yield, chemical composition and degradability of Zamboo grass (Hybrid jowar). MS. Thesis. Department of Animal Nutrition, Bangladesh Agricultural University, Mymensingh 2000.
90. Seo S, Kim J, Chung E, Kim W, Kang W. Effect of methods and rates of seeding on the forage production and nutritive value of sorghum × sudan grass hybrid grown under application of animal manure. J Kor Grassl Forage Sci 2000; 20:49-54.
91. Sheaffer C, Halgerson J, Jung H. Hybrid and N Fertilization Affect Corn Silage Yield and Quality. J Agron Crop Sci 2006; 192(278-283).
92. Sher A, Hassan FU, Ali H, Hassan W. Seed rate and nitrogen application effects on production and brix value of forage sorghum cultivars. Grassl Sci 2016; 62:119-127.
93. Sing D, Singh V, Joshi YP. Effect of nitrogen and cutting intervals on yield and quality of Napier Bajra hybrid. Range Management Dry Land Agriculture Research Project 14:1, Orissa University of Agriculture and Technology, Phulbani 762001, India 2000; 23:232-239.

94. Smith LED, Siciliano G. A comprehensive review of constraints to improved management of fertilizers in China and mitigation of diffuse water pollution from agriculture. Agr Ecosyst Environ 2015; 209:15–25.
95. Snyder R, Tegeder M. Targeting nitrogen metabolism and trans-port processes to improve plant nitrogen use efficiency. Front Plant Sci 2021; 11:2330.
96. Solomon S. Climate change, 2007. The physical science basis: Working group I contribution to the fourth assessment report of the IPCC Cambridge University Press. Systems, S.A. 2007. SAS user's guide, version 9.2. SAS Institute Cary, NC 2007.
97. Sosa RBA, Garcia VYS. Efficiency in the use of nitrogen in organically and mineral fertilized corn. Agron Mesoam 2018; 29(1):215–227.
98. Tahir MN, Riaz R, Bilal M, Nouman HM. Current standing and future challenges of dairying in Pakistan: A status update. Edited by Khalid Javed. Milk Production, Processing and Marketing. London, United Kingdom: Intech Open 2019.
99. Tamme T, Reinik M, Roasto M. Nitrates and nitrites in vegetables: Occurrence and health risks. Academic Press. Salt Lake City 2009; 307-321.
100. Tessema Z, Baars RMT, Alemu Y. Effect of plant height at cutting and fertilizer on growth of Napier grass (*Pennisetum Purpureum* Schumach). Trop Sci 2003; 43:57-61.
101. Thind HS, Bijay S, Pannu RPS, Yadvinder S, Varinderpal S, Gupta RK, Vashistha M, Singh J, Kumar A. Relative performance of neem (*Azadirachta indica*) coated urea vis-a-vis ordinary urea applied to rice on the basis of soil test or following need-based nitrogen management using leaf colour chart. Nutr Cycl Agroecosyst 2009; 87:1–8.
102. Tovar SH, Diovisalvi N, Carciochi WD, Izquierdo N, Sainz Rozas H, Garcia F, Reussi Calvo NI. Assessment of nitrogen diagnosis methods in sunfower. Agron J 2021; 113:2846–2857.
103. Trinh TH, Kushaari K, Shuib AS, Ismail L, Azeem B. Modeling the release of nitrogen from controlled release fertiliser: Constant and decay release. Biosys Eng 2015; 130:34–42.
104. Turgut I, Bilgili U, Duman A, Acikgoz E. Production of sweet sorghum (Sorghum bicolor L. Moench) increases with increased plant densities and nitrogen fertilizer levels. Acta Agriculturae Scandinavica, Section B — Soil Sci Plant Nutr 2007; 55(3):236-240.
105. Turgut I, Bilgili U, Duman A, Acikgoz E. Production of sweet sorghum (*Sorghum bicolor L.* Moench) increases with increased plant densities and nitrogen fertilizer levels. Acta Agriculturae Scandinavica, Section B - Soil Sci Plant Nutr 2005; 55:236-240.
106. Uddin MM, Khandaker ZH, Sultana MN. Effect of levels of nitrogen with or without phosphorus fertilizer on oat (*Avena sativa*) forage production harvested at various ages: I. yield and nutrients content. Bangladesh J Anim Sci 2005a; 34(1-2):63-71.
107. Villareal RM, Garc´ıa ERS, Osuna ET, Armenta BAD. Effect of dose and nitrogen source on yield and postharvest quality of tomato in fertigation. Terra Latinoam 2002; 20(3):320.
108. Wajid A, Ahmad A, Khaliq T, Alam S, Hussain A, Hussain K, Ahmad S. Quantification of growth, yield and radiation use efficiency of promising cotton cultivars at varying nitrogen levels. Pak J Bot 2010; 42:1703–1711.
109. Wajid N, Ashfaq A, Asghari B, Rabiu O, Muhammad U, Tasneem K, Muzzammil H. Effect of nitrogen on yield and oil quality of sunflower (*Helianthus annuus* L.) hybrids under sub humid conditions of Pakistan. Am J Plant Sci 2012; 3:243–251.
110. Wang M, Zheng Q, Shen Q, Guo S. The critical role of potassium in plant stress response. Int J Mol Sci 2013; 14:7370–7390.
111. Zahoor A, Riaz M, Ahmad S, Ali H, Khan MB, Javed K, Khan MA. Ontogeny growth and radiation use efficiency of *Helianthus annuus* L as affected by hybrids, nitrogenous regimes and planting geometry under irrigated arid conditions. Pak J Bot 2010; 42:42.
112. Zewdu T, Baars R, Alemu Y. Effect of plant height at cutting, source and level of fertilizer on yield and nutritional quality of Napier grass (*Pennisetum purpureum* Schumach.). African J Range Forage Sci 2002b; 19(2):123-128.
113. Zhang M, Gao B, Chen J, Li Y, Creamer AE, Chen H. Slow-release fertilizer encapsulated by graphene oxide films. Chem Eng J 2014; 255:107–113.
114. Zubillaga MM, Aristi JP, Lavado RS. Effect of phosphorus and nitrogen fertilization on sunflower nitrogen uptake and yield. J Agron Crop Sci 2002; 188:267–274.